

Solar Water Heating
Successes and Failures

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I. Introduction:

Between about 1975 and 1985 there was a great burst of activity in the solar thermal technology field. That activity created a vast proving ground for many concepts, concepts technological and otherwise. Some worked well, some needed improvement, and some did not work well at all. In an attempt to learn from our mistakes, his own as well as those of others, the author has been compiling some of those successes and failures.

Sunsearch, Inc. a business run by the author, provides service to over 8000 solar systems. This business has afforded us an excellent opportunity to observe what worked and what did not. Hopefully, the experience gained from an evaluation of the past 27 years of solar activity will benefit not only those who will design, install and service such systems, but also and perhaps most importantly, it will benefit those who will use them.

We have learned that: some incentives used to stimulate the use of solar energy worked and some were flawed; some attempts to regulate the solar industry worked and some need further attention; some aspects of the housing market negatively affect the use of existing solar equipment; solar water heating, solar pool heating, solar space heating, work; some forms of those systems worked quite well and some did not.

The following article offers a discussion of some of what we have learned from nearly 3 decades of daily involvement with solar thermal systems.

II. Politically Created Market Incentives:

A fledgling industry that is based on a sound economic demand for its products may have a chance to develop into a stable industry. A fledgling industry that is based on a politically created demand for its products is in for a rough ride. In the energy field it is very difficult to avoid the effects of politics on the energy picture in the United States.

From a politician's point of view there are two types of incentives that could be used to stimulate the solar industry: one is to make conventional forms of energy more costly; the other is to reward people for using solar energy. Both approaches work, we know that from what happened in the 1970's. They work in different ways. The rising cost of energy encourages conservation across all aspects of the energy consuming economy, it also encourage the use of renewables. But it does not require much political insight to realize that specific government legislation that increased the cost of energy would be most unpopular with the electorate. What politician who wanted to be reelected would support such legislation? Further, the across the board increase in the cost of energy would not specifically target the solar energy industry. Thus the incentives that were used were in the form of reward to those who paid to have solar equipment installed on their property. Some incentives worked better than others.

A. What was done:

a. Energy Prices:

The rising price of energy during the 1970's did not occur as a result of intentional legislation to stimulate the solar energy industry, although it served to do just that. During the winter of 1973/74, when the first OPEC induced oil shortage occurred, the price of energy was regulated by the federal government. Because of that regulation it was less expensive for US oil refiners to import crude oil than it was to use domestic oil. The dependance on imported oil left us vulnerable to OPEC. OPEC again took advantage of that vulnerability, when in 1978 and 1979 the price of crude oil more than doubled each year. The sharp spike in energy costs during the winter of 1973/74 was enough to start a few solar companies. Gradually, more companies entered the solar business, even though energy prices fell for a few years after the winter of 1973/74. In the late 1970's the price of energy again began to rise rapidly. The news was full of article about conservation, and the solar industry was growing.

Rising energy prices do encourage conservation and the use of renewables. But they are very unpopular with energy consumers.

b. Federal Tax Credits:

The most recent cycle of the solar thermal energy industry started in earnest in about 1975. It had as its impetus the rapid increases in oil prices that began in earnest in 1977. By the time the federal solar tax credits came into existence in 1978 they were almost not needed, so strong was the demand for solar equipment. Then in 1980 President Regan decided to deregulate the oil industry. Within in a few months the bottom dropped out of the oil market. In six months about the only economic incentives left to sustain the solar energy industry were the federal and state income tax credits. By the end of the 1985, when the tax credits were set to expire, President Regan chose not to renew them. In 1986 the solar thermal industry in the US went from over 350 companies nationwide to about 10 in a 6 month period.

In spite of the nearly total loss of a solar equipment manufacturing base, there was a significant benefit to the loss of the tax credits. It was the loss of the sales companies that had moved into the solar business in the early 1980's. They were comprised of a lot of people who had been chased out of the home improvement industry. A pattern for many of the sales companies was to set up phone rooms to work a given region for a period of time. They typically sold through sales seminars because the buyer's right of rescission did not apply to sales in that venue and because they could better control the 'show' on their own stage.

The sales companies aggressively used the tax credits to help sell the systems, enlisting homeowners as their partners in an effort to get back some of their hard earned money from the government that had taken so much of it away. Why pay \$4000. for a solar water heating system when you only received a tax refund of \$1600. (at 40% tax credit); instead, why not pay \$10,000 for the same system, then you get \$4000. back from the IRS. As specious as that argument may sound to the reader, thousand of people swallowed that argument.

Many of the sales companies became a caricature of the fly by night operation. They would contract with local installers to put in the systems. We would work an area for 9 months to a year. Once they had 'mined' the area they would close the business and move on to another area with a new company name. They typically sold systems at twice the price of other, reputable installers. When they moved on, the people who bought their systems were left with no one to service the system. Many were also left with a mortgage on the system that they had to pay regardless of whether the system worked or not. Many thousands of systems were installed by these sales companies. They gave the industry a very bad reputation.

The tax credits, which had been implemented with the best of intentions, became the most effective selling tool of the sales companies.

More recently, federal solar tax credits and an accelerated depreciation deduction were made law for commercial applications of solar equipment. These have helped in the commercial sector, but they are not a major incentive to the use of solar technology on the scale of the earlier residential tax credits.

On the plus side, the grants served to quickly demonstrate the solar concept. Many installations received extensive media coverage, which further served to stimulate public interest. The money spent for these demonstrations did help get the industry started.

On the down side, many of the systems installed by the demonstration grants have been removed or are sitting unused. A common complaint of the plant managers is that the systems are costly to maintain. They claim the cost of the repair exceeds the cost of the energy saved. A very common query from these folks is, if a government grant paid for these systems why can't a government pay for their maintenance.

d. Tax Shelters:

Before the tax reform of 1986 there were quite a few large, leased solar systems that were installed. The leased systems were installed with tax sheltered money. Investors in the 50% tax bracket were allowed to make a very high return on their investment by putting their money into tax sheltered, limited partnership accounts. By doing so they received an investment tax credit, plus a solar tax credit, in addition they were allowed to take an accelerated depreciation deduction on the solar equipment installed with their money. Returns of 50% per year were realized.

On the plus side, a lot of large solar systems were built using tax sheltered funds.

On the down side, many of those systems were of the poorest quality imaginable. Since the money to be made was from the tax shelters, and not from the savings produced by the system, the investors in those tax shelters had little interest in the system once it was completed. The installed systems were required to provide an income stream to the limited partnership, and that stream was based on the savings in conventional costs realized by using those solar systems. In addition to the many abuses to the reported savings claims, the income stream from the system was tiny compared to the tax credits and depreciation deduction. Thus there was little incentive to maintain the systems.

B. What might be done - the next time:

a. Increase the demand for solar thermal technology, this could help to reduce the cost, thereby making it more accessible to others. The federal government is said to own and manage more real estate than any other organization in the world. Require the use of solar thermal equipment on all federal civilian and military buildings.

Begin with a phased program that requires that the more cost effective solar technologies, such as solar water heating and solar make-up air systems, be used as a supplement to conventional fuel systems on all new government buildings. Drop the present requirement that solar be used only if it can be justified economically.

Retro fit all military housing with solar water heating and utility-tie solar electric systems. Where architecturally compatible, require the retrofit of solar thermal and solar electric systems on existing government buildings. b. Encourage the use of energy conservation as well as the use of solar thermal technology through a long term, announced, program of incremental sales taxes applied to the cost of conventional fuels. Do this until there is fuel cost parity in this country with western European countries. The doubling time on a 10% per year rate of increase is about 7 years. It might take 20 years before we reached parity with western European fuel costs. Do this so that fuel costs increase at the rate of 10 % per year. The slow incremental rate will allow gradual adjustments in our economy and personal life style. People would have plenty of time to upgrade insulation in their homes and to trade in less fuel efficient vehicles. This could be similar to the gradual increase in cigarette taxes. Note that gradual increases in cigarette taxes have been such that cigarettes are now \$5.00/pack in NYC. This would encourage conservation and stimulate the use of solar technology. Nothing makes a solar company's phone ring like higher fuel costs.

Use the tax revenues to fund the use of solar systems on government buildings; to subsidize conservation projects for low income housing and low income home owners; and to fund solar demonstration projects, electrical vehicle use, etc.

What elected official might we find who would propose and sponsor such legislation?

c. Impose a law that requires that for any water heater replacement and for new water heater installations, the replacement heater or new heater must be a solar water heater, and that any type of supplemental water heater can be used. This law existed in Australia for a number of years and then was abandoned. It was imposed in one county in California during the 1970's. I have been told that it was dropped, but have been unable to find out why.

d. Tax Credits: If they must be used then perhaps the better approach is to follow the present tax credit and accelerated depreciation incentive for commercial systems. This is by no means as powerful an incentive as the 40% federal solar tax credit but it does significantly improve the return on investment in the solar system.

III. Industry Regulation:

A. Building Codes:

In order to set some minimum standard for solar system installation the federal government established a model code for solar water heating systems. Many of the 5 model codes used nationwide adopted that model code. Some state governments chose to include the solar code in their model code and others chose to develop their own version.

On the up side, the model solar code was a good idea. It gave a uniform standard for solar thermal system installation.

On the down side, some state codes that were not based on the model code were unnecessarily restrictive. In addition, they tended to be prescriptive rather than performance oriented. Many installers chose to ignore the codes. As long as they were able to get away with out applying for a building permit, they were successful.

B. Solar licensing programs:

By the early 1980's many states were offering solar training in their trade schools. By developing a pool of licensed solar technicians, states attempted to establish some minimum level of competence for those installing solar systems.

That was and is a very desirable objective. States varied widely on their approach to this. .

On the downside, a lot of solar system installers did and still do wiggle through the cracks. That is, they install systems without being licensed. Unless there is a problem with the work done, and the system owner files a written complaint, the local code official and the state government don't know of unlicensed installers working in their areas.

One might think that the building permit process would keep out the unlicensed installer. In order to apply for a building permit for a given type of work the contractor licensed to do that type of work must apply for a permit and show his or her contractor's license to the building official. No license, no permit. Unfortunately, it does not always work that way. Particularly on retrofit work, solar installers often do the work without a permit. If the installer does not apply for a permit then he does not have to show a license. The town that issues the building permits may not know that the work was done until the next property tax reassessment. Those are typically 10 years apart.

C. Performance Standards:

Performance data is available on various solar thermal components as a result of the actions of various professional societies. The ASHRAE standard for testing solar collectors provides useful data to those wanting to specify solar thermal collectors. And the data published by the Solar Rating & Certification Corporation, SRCC, on solar system performance is valuable for anyone wanting to compare the products of different manufacturers.

On the up-side, this information is useful to anyone selecting a system or component.

On the down side: few consumers know of these performance standards. Further many sales companies did not bother with them. They were able to sell large numbers of systems with-out referring to these or other standards.

IV. Areas of Ignorance:

A. Real estate Agents: Ignorance in this sector of our economy has probably been responsible for the removal of solar systems than any other factor. The agents often don't understand the systems so they tell prospective sellers to remove it prior to showing the house rather than have something on the house that jeopardizes the sale.

B. Home Inspectors: Few home inspectors know anything about solar energy systems. They will usually exclude the solar system from their inspection, which is not bad. But some will tell the prospective buyer that the system doesn't work and that it should be removed to facilitate the house sale.

C. Roofing contractors: When a house roof is reshingled the roofing contractor usually wants the solar collectors out of the way. The easiest way for him to deal with this obstacle is to tell the homeowner that he removes systems all the time. Further, he will often tell the homeowner that everyone is doing that. Many homeowners who are not the original owner of the solar system will go ahead with the suggestion, rather than cope with the added headache and expense of finding someone to remove and remount the solar array.

V. Other:

A. Solar Access:

Solar access is a problem for many existing systems. For a solar water heating system on a fixed mount to deliver the maximum amount of heat year round the collectors should receive full sun from about 9:00AM to 3:00PM. If trees have grown up to shade the collectors and the shade is substantial then the system is really not able to deliver much heat during the shaded period. That period of shade could be all winter or even all year.

If evergreens are shading the collectors, nearly all system owners recognize the negative effect of the shade and will take action, when they can, to remove or trim the offending trees. However, if the trees are deciduous, most people believe that when the leaves fall the shade is not significant. Not so. Studies done years ago showed that deciduous trees without their leaves often cast shade equal to between 40% and 60% of complete shade. Look at the tank temperature of a solar water heating system with collectors shaded by deciduous trees at the end of a sunny winter day. The low tank temperatures will reveal the true extent of the shading.

When the collectors are shaded by trees on the system owner's property the owner will usually have the offending trees pruned or removed. However, when the trees are on a neighbor's property we find that system owner's are rarely successful in negotiating with the owner of the offending trees to have them trimmed or removed.

The only way to prevent this from happening is to enact local solar access laws. These laws might enable the owner of a shaded solar array to pay the costs of having his/her neighbor's trees pruned.

B. Fuel Oil suppliers:

Perhaps as much as real estate agents, and roofing contractors, fuel oil service companies have been responsible for the removal of many existing solar water heating systems. As the roofing contractors, they tell the homeowner that the solar system does not save any money and that they should shut it down, or remove it. Many offer to remove the system at no charge. A properly working residential solar water heating system can save its owner between 300 and 400 gallons of oil a year. That is money out of the fuel oil supplier's pocket. No wonder he wants the system shut down.

VI. Solar Water Heating Technology:

If economic justification for a solar water heating system is required, one usually looks for solar system applications that require thermal energy year round. The following are listed in the order of most economically attractive active solar thermal applications:

- a. Solar heating of outdoor swimming pools:
An exception to the year-round use objective;
- b. Solar heating of domestic water;
- c. Solar spa (hot tub) heating;
- d. Solar space heating:
An exception to the year-round use objective;
- e. Solar heating of indoor pools

The following is a partial compilation of what worked and what did not among solar thermal systems. The compilation deals largely with active solar systems. Unfortunately, it is not based on a careful statistical analysis of all the available systems; instead it is based on the first hand experience of a single company that services about 8000 solar systems. Among those 8000 systems is a great diversity of system types.

A. System Types that worked:

There are a variety of design constraints that solar thermal systems must meet. Two constraints that we have found to have a notable effect on system reliability are the capacity to deal with freezing conditions during the winter and with overheating conditions during the summer. The need to cope with freezing conditions may seem obvious in the Northeast; the need to cope with overheating arises from systems that have no demand for heat during hot weather. Many early system designers did not anticipate the latter. A variety of ways have been devised to cope with these conditions.

The two collection system types that have proven the most reliable in the Northeast are:

- a. Closed loop antifreeze systems
- b. Drain back solar systems

Closed loop, antifreeze system: this is by far the most common type of solar water heating system found in the Northeast. The collectors, the piping between the collectors and heat exchanger in or near the storage tank are completely filled with some type of low freezing point solution. Typically the fluid pressure is 30 to 35 psi. A control turns on a pump that circulates the antifreeze between the collectors and the heat exchanger when the collectors are warmer than the storage container. The closed loop systems cope with freezing by using some type of low freezing point liquid, typically a propylene glycol based antifreeze. This protection does not require any involvement of the system owner other than to be sure that antifreeze is used in his system.

Whether or not over heating is a concern, depending upon the type of antifreeze solution used. If an a propylene glycol based antifreeze is used, and the system overheats, the antifreeze is likely to vent from the collector loop if there is no hot water demand for several days and very clear sky conditions occur. Loose enough antifreeze and the system will no longer collect heat.

The closed loop systems cope with overheating either by using a high boiling point antifreeze, such as a silicone, or by some active involvement of the owner. If a high boiling point liquid is used then nothing needs to be done to cope with overheating. If an aqueous based antifreeze solution is used then, when the owner anticipates no hot water demand during the summer for more than about 2 days, he/she should set the switch on the pump control to “on” so the pump will run day and night while the owner is away. Doing that causes the system to dump the excess heat collected during the day to the atmosphere during the night. Upon returning from being away the owner resets the pump control switch to “auto”. This is not a fully automatic means of coping with overheating but it works in most cases where the collector area is not badly oversized for the storage tank.

The closed loop systems are used for domestic water heating, spa heating, space heating and indoor pool heating.

Drain back system: These systems did not find wide commercial use until the early 1980’s thus fewer were installed. It is also a somewhat more expensive system than the closed loop system which also contributed to its lower numbers. When the system is off, the collectors, the piping between the collectors and the reservoir, which is usually indoors near the storage tank, are empty. When the system is running, a pump lifts either water or some type of low freezing point solution through the piping to the collectors. There the liquid picks up the sun’s heat and returns it to the reservoir. The pump maintains circulation until either the collectors cool to a temperature slightly above that of the storage tank, or until the storage tank reaches some preset high limit, then it shuts off. In this way the drain back system automatically copes with both freezing and overheating conditions. These systems may be either closed or open to atmospheric pressure.

The drain back systems are used for outdoor pool heating, domestic water heating, spa heating and space heating.

B. Materials & Assemblies that worked:

Some of the materials below have some drawbacks for the application, where those are believed significant, they are noted.

Flat plate air-cooled collectors when used for space heating;

Materials used in their construction are important, details not covered here;

Flat plate liquid cooled collectors when used for water heating;

Materials used in their construction are important, details not covered here;

Aluminum enclosures for solar collectors;

Aluminum collector mounting structures;

Propylene glycol formulations that came available in the late 1980’s;

Early propylene glycol formulations were unbuffered and typically lasted 2 to 5 years; one currently available formulation is still unchanged after 12 years in thousands of systems;

pvc piping for solar pool heating systems;

Selective coatings on collector absorbers:

The increased heat collection due to the use of these coatings over flat black paint is significant in cold climates like the northeast; a drawback to their use is that the closed loop systems using propylene glycol antifreeze are likely to overheat during the summer months when there is no hot water load, whereas overheating has not been a problem with collectors using flat black painted absorbers;

Stone-lined hot water tanks by Ford Products Corp.;

With a few exceptions, their tanks typically lasted 15 to 20 years; unfortunately the company did not survive the recession during the early 1990's.

Silicon oil and bray oil heat transport fluids;

Valued for use in closed loop systems because of its stability and high boiling point, silicon oil has a tendency to leak from threaded joints, making the closed systems difficult to seal; silicon oil also requires a circulator 3 times the wattage of that used in the glycol based systems; unfortunately silicon heat transport fluid is no longer available; bray oil is still available;

isocyanurate pipe insulation;

Best thermal insulation per inch thickness that one can buy, must be protected from sunlight by a PVC wrapper;

Foil faced and backed isocyanurate insulation used in collector enclosures;

Present day versions of differential thermostats and their thermistor sensors;

They are still vulnerable to power line surges but far less so than earlier models;

Copper tubing for solar collector supply and returns lines;

Factory built solar collectors, for the most part;

About 70% of the solar collectors built in the US between 1975 and 1985 should have a 50-year life;

Water and pebbles as thermal storage media;

Water tanks may leak, but water and rock seem to endure pretty well!

Stainless steel solar heat storage tanks w or w/o internal heat exchangers;

All tanks leak, some sooner than others, stainless steel tanks generally last longer than other types and leaks that do develop can be repaired by welding;

Surge suppressors for protecting differential thermostats;

Power line surges play havoc with many electrical components; surge suppressors offer another layer of protection for pump controls;

Lightning grounding for collector supply and return lines;

Not normally used, unless the system is in a locality where frequent lightning strikes occur, then grounding will reduce damage to electrical components such as pumps and controls.

Glass glazed solar collectors - low iron tempered glass;

Many feared that glass breakage would be a problem with solar collectors, it has been a minor problem; out of the 8000 solar systems that we service there are less than 5 service calls a year to repair broken glass glazings.

Aluminum fasteners for collector enclosures;

Stainless steel fasteners for collector mounting hardware;

Copper tube and sheet absorbers;

One type of evacuated tube solar collector:

The Sunmaster evacuated tube collector has held up better than any of the other evacuated tube collectors that were installed during the 1975-1985 period; unfortunately the collector is no longer available; the manufacturing equipment was sold to a Korean manufacturer and has since been scrapped;

Copper heat exchange coils inside stone lined hot water storage tanks.

At the start of the solar water heating industry much was made about the likelihood of the heat exchanger leaking, thereby allowing potentially toxic antifreeze into the hot water tank, this has not been a problem, to date we have found none that have leaked, the tank leaks long before the heat exchanger;

Solar' flashing boots for collector supply and return lines where they penetrate a roof:

C. System Types That Had problems:

Passive solar water heating systems in freezing climates;

Those that circulated domestic water through the collectors (water circulated when a tap was opened) often experienced freeze damage where the collector went through the roof, heat tapes wrapped around the piping where it passes through the roof protect the pipes from freeze damage as long as electric power is available, unfortunately power outages can and do result from winter storms;

Heat pump assisted solar systems:

The concept is wonderful, but finding someone to service and repair these systems is quite difficult;

Suntracking type solar collectors:

The tracking approach lets them collect more heat during the summer months than a fixed collector array, but the maintenance on the tracking mechanism has been far more costly than the on fixed arrays;

Air-cooled heat collection systems are quite good for space heating but not so good for domestic water heating:

If the water heating is incidental (not the primary reason for the system having been installed) then this can be acceptable provided some reliable means is used to prevent freezing of the domestic water heat exchange coil, few successful water heating only applications have been found;

Closed loop liquid cooled systems with oversized (for the load) collector arrays:

They overheat frequently during summer weather if there was no load or a small load, overheating requires replacement of the lost antifreeze;

Percolation-type solar water heating system:

One type that was widely promoted in the US has no realistic provision for dealing with overheating that results from no hot water demand for a prolonged period, covering the collectors whenever the owner is away works but seems impractical if this is to be sold to a mass market;

D. Materials and assemblies that had problems:

Early propylene glycol formulations:

The glycol became acidic quickly and had to be replaced every 2 to 3 years;

pV powered circulators for solar water heating systems:

When the sun shines the pV driven circulator sends heat to the storage tank during the day, whether it is needed or not; the circulator cannot be operated at night to cool off the tank, result, the collection loop overheats during the summer months when there is no hot

water load, antifreeze must be replaced and water may vent from the tank relief valve into the owners home when he/she is away;

Stone-lined tanks now available;

At present there is just one manufacturer of stone lined tanks; the tanks vary widely in longevity, somewhere between 8 and 14 years seems average; the heat exchanger port on these tanks requires repeated tightening due to the elastomeric boot used to seal the tank at the heat exchanger port; an unacceptably high percentage fail during the manufacturer's warranty period; quite a few solar system owner's have removed or abandoned their solar systems when their third or fourth tank leaked in a 15 or 20 years of solar system ownership; what is puzzling is that this manufacturer makes a stone-lined electric water heater tank that often lasts 20 to 30 years;

Sol-a-roll epdm rubber absorber material:

While epdm 'rubber' is a very durable material when used as a roof membrane or as a tank liner it was not a particularly good absorber material for closed loop systems; it had no oxygen barrier thus the glycol in the collection loop quickly became acidic; cast iron circulators commonly used in such systems often corroded; further, the means by which the tubing was attached to its manifolds often resulted in the tubing being blown out of the manifold when the antifreeze was replaced; it was better applied as a solar pool heating absorber, but even in that application the adhesive used to hold it to shingles was not very effective; the sol-a-roll material is no longer available;

Site built solar collectors - for the most part;

Site built collectors were often made an integral part of the roof membrane, rather than mounted on top of the roof membrane; they were often glazed with a rigid plastic sheet; In many of these systems there have been costly leaks into the house below; the plastic glazing becomes cloudy in 7 to 10 years and must be replaced, the wood frame that was often used to form the enclosure for the absorber has deteriorated in 10 to 15 years; in some there have been fires due to the heat build up during the summer when there is no demand for heat; Perhaps the most successful site built collectors were those made by Acorn Houses, beginning in about 1985; they mounted the collectors on top of the roof membrane and finally changed to glass glazed collectors with aluminum mullions to hold the glass.

Hot water storage tanks placed high in houses - upper floors or attic:

This is the preferred tank location if a passive solar water heating system is to be used, so the collectors can be located lower than the tank, unfortunately, if the tank leak goes unnoticed because it trickles into a small drain and then the tank ruptures, a lot of property damage is likely to occur;

Back flow preventers for solar water heating systems:

Required by health codes to prevent the possible backflow of contaminated water in solar tanks into the potable water supply system; the back flow could occur if the main pressure were zero or even negative; the water in the solar tank could be contaminated by a leak in the heat exchanger; the backflow preventers frequently leak water out through their vent; dirt carried by the water passing through them will cause them to leak; they also seem to leak large quantities of water for no apparent reason; they typically need replacement every 5 to 7 years; but we have had to replace as many as 3 in one year

Conventional flashing boots for collector supply and return lines:

They seal tightly around the exterior of the pipe insulation passing through the roof, but rain water is often able to make its way into the house past the boot by running between the pipe and the insulation, the rain water leak causes damage to the interior of the building below the piping;

Pumps in drain back systems with inadequate net positive suction head:

The high head pumps used in drain back systems require several feet of water column above the suction inlet to the pump, this is to prevent excessive cavitation in the pump; many drain back solar water heating systems were not installed with adequate suction head, thus the pumps tend not to last as long as those used in systems with adequate suction head;

Automatic air vents at the top of closed loop solar systems:

They leaked when left open to vent the air in the system;

E. Other things that had problems:

Training of qualified technicians:

Finding qualified technicians is difficult, at one time trade schools did offer special training to students aspiring to be solar mechanics for solar thermal system work; today those solar oriented courses are not offered. The closest trades are plumbing and heating but the students from these programs require a lot of training before they can be useful solar mechanics;

F. System Types That did not work

Open loop, recirculation type solar water heating systems in cold climates:

While these seem appropriate for warm climates such as Southern California, where only a few days or weeks of freezing weather occur each year, they have not proven suitable for the Northeast. The rate of recirculation is not sufficient to prevent freeze damage;

Closed loop antifreeze systems with oversized collector arrays:

A number of such systems were installed to provide a small percentage of the space heating requirement and some portion of the domestic water-heating requirement; these systems have had frequent overheating problems during the summer when the hot water demand is only a fraction of the heat collected; antifreeze recharging is required when they overheat;

Open loop, drain down solar water heating systems in cold climates:

No one seems to have been able to make a fail safe version of this system type; nearly all have suffered freeze damage to the collectors and exterior piping because the system did not drain down when it was supposed to; repairs to freeze damage collectors are costly, unless homeowners insurance covers the repair the system is usually abandoned;

G. Materials and assemblies that did not work:

Many evacuated tube solar collectors:

There were several types of evacuated tube solar collectors that did not work, the GE collector was probably the poorest design, it was quite vulnerable to breakage by thermal shock; another design used the same tube as Sunmaster but its absorber design was poor; the North American Philips tube with the internal heat pipe seemed a good concept but the thermal performance was very low due to poor heat transfer between the heat pipe and the fluid to be heated;

Automatic make-up water lines to closed loop solar water heating system:

These apparently made sense to some consulting engineers because they were so widely used in large systems: they caused the dilution of the antifreeze in the collection loop which eventually resulted in freeze damage to the collector array; their use was responsible for the removal of a number of large systems in the southern New England area; Sun-temp heat transfer oil:

This material literally dissolves shingles; it also rapidly deteriorates bladders in expansion tanks and pump seals;

Sunwave a glazing scheme used for glazing Acorn solar collectors:

The material they used, filon, becomes cloudy over time reducing the amount of solar energy reaching the collector absorber by 60% or more; while filon is no longer available, the material that is available, another fiberglass glazing, is very difficult to install in the mullions used to hold the filon in the wave form; Acorn eventually recognized the problem and switched to glass glazed collectors during its last year in the solar business;

Plastic film glazing used by Reynolds Metals Co. for solar collectors:

The outer glazing lasted no more than 10 to 15 years in most instances; most original installations of the material have fallen apart, better materials were available at the time it was used, in fact Reynolds switched to glass glazed collectors during its last year in the solar business;

Aluminum roll-bond absorbers for solar collectors:

The aluminum corroded through rather quickly;

Polybutylene piping for solar collector supply and return lines:

The material melted in many installations, most of the time the melting occurred at or near the collector outlet; it also offers no oxygen barrier, which results in rapid deterioration of the glycol;

Painted mild steel collector mounting frames and fasteners:

They rust badly, and thus are difficult to remove when the collector array must be removed and remounted for reshingling;

Pvc piping for solar collector supply and return lines:

The collection loop fluid is too hot for the PVC, it causes the pvc to melt and leak;

Pvc pipe insulation for solar water heating systems:

Pvc pipe insulation may be a good low temperature insulation, but when used on collector supply and return lines it melts at the high collector operating temperatures;

Sun-strip absorber material:

over time it develops leaks, the leaks can be repaired by careful cleaning and soldering, but more leaks will develop, the interior layer of copper is too thin; a later version of the material has a copper tube inside the aluminum fin, this should last longer;

Thermal storage materials other than stone or water:

None of the thermal storage materials that we have encountered that required a nucleating agent to establish a fixed melting point have retained that melting point;

Solar collectors made an integral part of the weather membrane:

In most cases they leak, and the cost of the efforts to prevent them from leaking do not seem justifiable;

Mounting solar collectors directly in contact with a roof surface:

Ice dams build up on the upper edge of the collector array; the roof surface deteriorates in that area and under the collector and eventually leaks;

Sealed double glazed glass glazings for solar collectors:

The seals used cannot withstand the differential thermal expansion that occurs between the inner and outer sheets of glass, the seal breaks and the space between the glass becomes clouded with moisture; over the long term lime is leached from the glass in the space between the two sheets of glass;

Solar collectors with painted steel or wood enclosures:

The protective coatings that were used did not hold up, once the enclosure starts rusting it can be slowed, if discovered, but not stopped; often the rusting is not discovered until the enclosure is badly rusted;

Steel or wood mounting structures for solar collectors:

Neither has held up well in this application, the steel rusts, and the wood, even pressure treated wood, rots;

p/t relief valves used in the collector return line:

Fills basement with glycol vapor on clear day with no hot water load.

Pressure relief valve installed at the collector outlet of closed loop systems using antifreeze: the system overheats when there is no hot water load, antifreeze is lost on the roof and system owner is not aware of the loss; this approach works fine where open loop systems are used in climates like that of Florida.

VI. Summary:

If we compare the current state of our 'industry' with that during the 1975 to 1985 period, it is difficult to claim that we in fact have much of a solar thermal industry in the U.S. We do have solar thermal equipment manufacturers. There is a fairly active solar pool heating market nationwide. There is an active solar water heating market in Hawaii. Aside from those notable exceptions, relatively few of the solar thermal products manufactured in the US are being sold in the US. Most are being sold in the Caribbean, in Western Europe, and on the Pacific Rim.

True, there are a number of people in the US who are interested in using solar energy for cost saving as well as for environmental reasons and these folks comprise the customer base for the relatively small number of companies engaged in selling and installing solar thermal systems. With the exception of solar pool heating, energy is presently too cheap to expect that a majority of the population will pay the high up-front cost for solar equipment.

While we are awaiting the day when there is a much stronger demand for solar thermal products we have an opportunity to build a far more extensive and complete information base than has been offered here. Hopefully, it will be one that is more objective than this one. If we believe there will someday be a solar energy industry then certainly those who follow us will find the benefit of our experience most valuable.

Absent much higher energy costs, we can look forward to the same relatively low level impact of the solar thermal industry on the amount of non-renewable energy used in the U.S. If a higher level of solar activity is desired, then some way must be found to stimulate the industry. That way must be politically palatable, so that an elected official will propose and support it.

Author's Background:

The author has been actively involved in the solar energy field since 1973 when he founded a company to manufacture and market solar thermal technology. Between 1975 and 1982, that company, Sunworks, Inc., became the largest manufacturer of flat plate solar collectors in the world. The author also founded Sunsearch, Inc. in 1975. Sunsearch designs, services and installs all types of solar energy systems. Our primary market area is southern New England. We have a customer base of slightly over 8000 solar systems that we service. These systems represent a large variety of system types.

In addition to operating a solar energy business, the author was until recently an associate professor at the Yale School of Architecture, where he taught courses in building environmental control systems. These courses included: heating, ventilating and air conditioning systems, plumbing systems, electrical systems, and fire safe design. Energy conservation and solar technology were an integral part of most of the courses that he taught. In June of 1998 the author retired from teaching after 26 years at the School of Architecture.